Some thoughts, outcomes & potential applications from the feed efficiency project

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Feed Efficiency Measures

- **Milk Yield (lb) / DMI (lb)**

  - **e.g. 80 lb / 50 lb = 1.6**
    - Herd, Pen or Cow Level
      - Measurement of Milk Yield by Pen?
      - Measurement of DMI?
        - Formulated, Mixed & Delivered, Consumed DM

Feed Efficiency Measures

- **3.5% FCM (lb) / DMI (lb)**

  - **e.g. 80 lb Milk @ 3.7% vs. 3.4% Fat; 50 lb DMI**

    - **82.6 lb / 50 lb = 1.66 vs. 78.7 lb / 50 lb = 1.57**
      - Measurement of Milk Composition by Pen?
      - Measurement of Milk Yield by Pen & DMI?

  3.5% FCM = (0.432 x lb of milk) + (lb of fat x 16.23)
  4.0% FCM = (0.4 x lb of milk) + (lb of fat x 15)

Feed Efficiency Measures

- **ECM (lb) / DMI (lb)**

  - **e.g. 80 lb Milk @ 3.7% Fat & 3.2% Protein vs. 3.4% Fat & 2.8% Protein; 50 lb DMI**

    - **82.9 lb / 50 lb = 1.66 vs. 77.5 lb / 50 lb = 1.55**
      - Measurement of Milk Composition by Pen?
      - Measurement of Milk Yield by Pen & DMI?

  ECM = (0.327 x lb of milk) + (lb of fat x 12.95) + (lb of protein x 7.2)

Feed Efficiency Measures

- **ECM / DMI vs. Milk / DMI**

  - **e.g. 80 lb Milk, 3.7% Fat, 3.2% Protein, 50 lb DMI vs. 60 lb Milk, 5.2% Fat, 3.8% Protein, 45 lb DMI**

    - **ECM**
      82.9 lb / 50 lb = **1.66** vs. 76.4 / 45 = **1.70**
    - **Milk**
      80 lb / 50 lb = **1.60** vs. 60 / 45 = **1.33**

Gross vs. Partial Feed Efficiency

- **Gross Feed Efficiency**
  - **Total Output / Total Input**
  - **Increases as milk yield increases**
    - **Due to dilution of fixed costs in maintenance**
      - **Proportional to body size**
- **Partial Feed Efficiency**
  - **Also called net, marginal, or true efficiency**
  - **Increased Output / Increased Input**
  - **May be constant even as milk yield & gross efficiency increase**

The dilution of maintenance eventually disappears
M. VandeHaar, 2014

Pounds of 3.5% fat milk per day for a 1500 lb cow: 33, 67, 100, 133

A cow at 4X Maintenance has total requirement or intake of NE at 4X its NE requirement for maintenance.

NE maint = $0.08 \times BW^{0.75} = 10.7$ Mcal for 1500 lb cow
3.5%fat milk is ~0.32 Mcal/lb. So a cow producing 100 lb milk requires 43 Mcal NE = 4 x 10, or 4X maintenance.
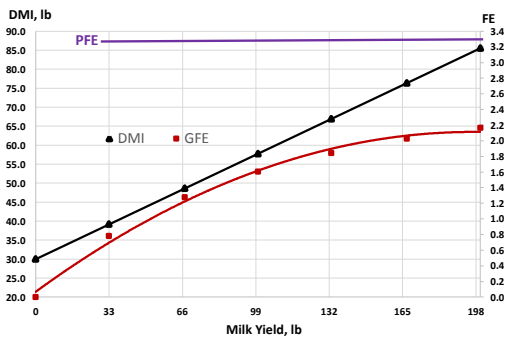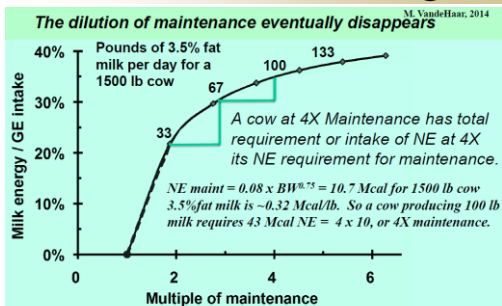
As productivity increases, gross efficiency increases but the incremental advantage diminishes. In addition, as cows eat more, they digest feed less efficiently, so this curve should plateau at 5X.
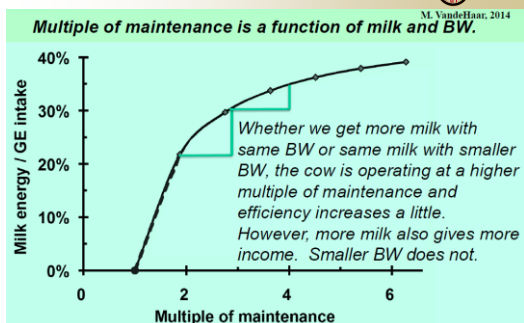
Multiple of maintenance is a function of milk and BW.
M. VandeHaar, 2014

Whether we get more milk with same BW or same milk with smaller BW, the cow is operating at a higher multiple of maintenance and efficiency increases a little. However, more milk also gives more income. Smaller BW does not.

Increase milk with same body weight⟶
Decrease body weight with same milk ⟶

Phenotypic (lower left) and genetic (upper right) correlations for feed efficiency
M. VandeHaar, 2014

	Milk E	Met BW	DMI	Gross Efficiency
Milk E		.07 ± .04	.73 ± .03	.61 ± .04
Met BW	.16 ± .02		.40 ± .03	-.14 ± .05
DMI	.60 ± .01	.37 ± .01		.04 ± .06
Gross Efficiency	.47 ± .01	-.05 ± .02	-.17 ± .01	

Data from 4450 cows in midlactation in US, NL, and UK.

For Holsteins at a multiple of maintenance around 4,

- selection for smaller body size may benefit feed efficiency but its impact will be slight compared to selection for more milk.
- direct selection for body size (either larger or smaller) is likely not warranted as a means to enhance production, feed efficiency, or profitability

Flow of feed energy
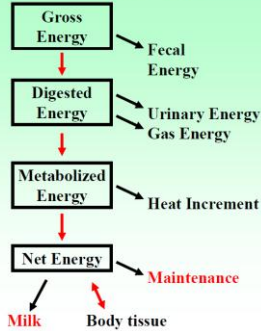
M. VandeHaar, 2014

Gross Energy → Fecal Energy

Digested Energy → Urinary Energy / Gas Energy

Metabolized Energy → Heat Increment

Net Energy → Maintenance

Milk   Body tissue

Feed efficiency has three parts:
1. How efficient is the total feed energy converted to Net Energy?

2. What fraction of the Net Energy is captured in milk and body tissues?

3. What fraction of the captured energy is partitioned to milk?

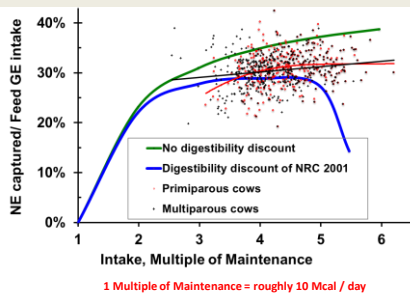# Digestibility Decline at High DMI

NE captured/ Feed GE intake

- No digestibility discount
- Digestibility discount of NRC 2001
- Primiparous cows
- Multiparous cows

Intake, Multiple of Maintenance

1 Multiple of Maintenance = roughly 10 Mcal / day

VandeHaar, 2013   14

M. VandeHaar, 2014

Residual feed intake (RFI) can be used to identify efficient cows independently of level of production.

Observed DMI
$$= \mu + b_1*\text{MilkEnergy}$$
$$+ b_2*\text{BW}^{.75}$$
$$+ b_3*\Delta\text{BodyEnergy}$$
$$+ \text{cohort}$$
$$+ \text{RFI}$$

RFI

Efficient cows have negative RFI

Observed DMI (kg/d)

Predicted DMI from NEmilk, mBW, NEg, and cohort
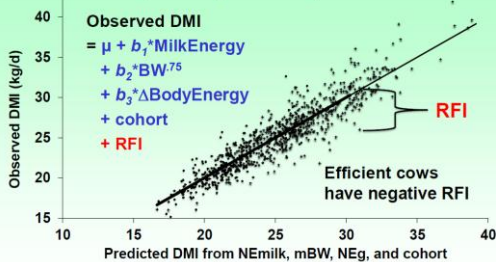
We don't have intake of daughters on farms. Genomic breeding values for efficiency are our only option.
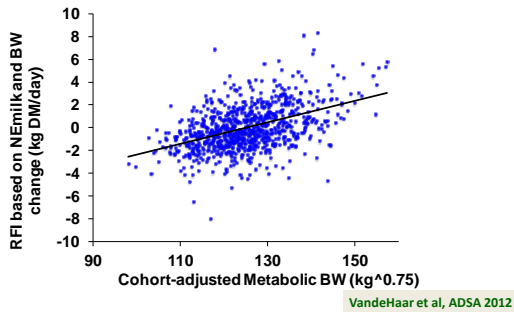
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Using RFI based on milk (and body weight change) but not excusing cows for body weight. Also shows bigger cows inefficient (more positive RFI)

VandeHaar et al, ADSA 2012

Use of genomic information to predict RFI

- Cannot constantly measure RFI in progeny testing as we do for milk yield

- **If** RFI heritable, can estimate from newly obtainable genomic information

- Hopefully, can select cows genomically for negative RFI

Trait Definition

RFI = Observed DMI - Expected DMI

where:
- **Expected DMI = Expected intake based on NRC equations for energy requirements of milk production, body weight, and body weight change**

or

- **Expected DMI = Average intake of cows in the same cohort or contemporary group, after adjustment to a constant level of milk production, body weight, and body weight change**
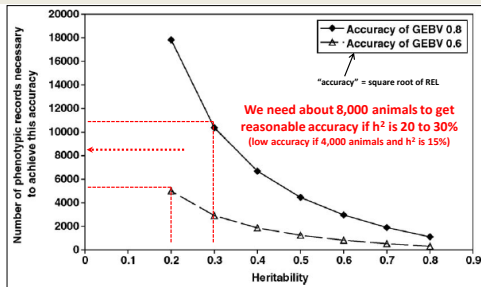
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Reference Population

"accuracy" = square root of REL

We need about 8,000 animals to get reasonable accuracy if h² is 20 to 30%
(low accuracy if 4,000 animals and h² is 15%)

Genomic Predictions

Table 1. The overall mean, estimates of genetic variance (VarG), proportion of phenotypic variance accounted for by SNP (Mh^2), and Pi, such that 1-Pi represents the proportion of SNP fitted in the genome wide association analyses, for traits related to feed efficiency.

Total of 2,894 cows, including 1,645 from the U.S., 797 from the Netherlands, and 452 from Scotland

Trait[a]	Mean	VarG	Mh^2	Pi
DMI	21.8	1.54	0.26	0.93
NE$_L$	26.9	3.27	0.22	0.91
MBW	118.9	22.50	0.38	0.92
NEg	0.39	0.17	0.02	0.98
RFI	0	0.27	0.14	0.91

[a]DMI = dry matter intake (kg/d); NE$_L$ = net energy for lactation (MCal/d); MBW = metabolic body weight representing maintenance energy requirements (MCal/d); NEg = net energy associated with change in body weight gain adjusted for body composition (MCal/d); RFI = residual feed intake (kg/d).

Selection Index

Current Net Merit	**"Wild Guess" Net Merit with RFI**
19% Fat Yield	**-19% RFI**
16% Protein Yield	**18% Productive Life**
22% Productive Life	**15% Fat Yield**
-10% Somatic Cell Score	**13% Protein Yield**
7% Udder Composite	**9% Daughter Pregnancy Rate**
4% Feet & Legs Composite	**-8% Somatic Cell Score**
-6% Body Size Composite	**6% Udder Composite**
11% Daughter Pregnancy Rate	**-5% Body Size Composite**
-5% Calving Difficulty	**-5% Calving Difficulty**
	3% Feet & Legs Composite

What about nitrogen efficiency?

- Dietary Protein more expensive than energy
- Nitrogen inefficiency has environmental costs as well
- Unlike energy, gross daily efficiency of N use by a lactating cow is maximized at less than maximum milk production!
  - We feed enough protein for max production, not max N efficiency
  - Increased milk protein production per day improves herd efficiency by diluting N use of replacements and dry cows
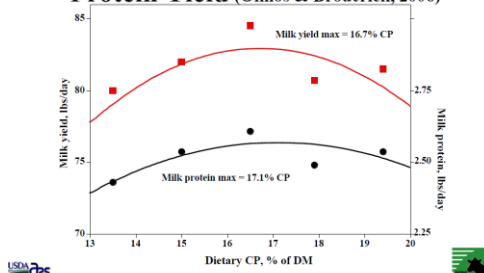

Effect of CP (Solvent SBM) on Milk & Protein Yield (Olmos & Broderick, 2006)

Milk yield max = 16.7% CP

Milk protein max = 17.1% CP

Dietary CP, % of DM

Effect of Dietary [CP] on Intake, Yield & Urinary N (Broderick, 2003)

Dietary Crude Protein, % of DM

Slide 1
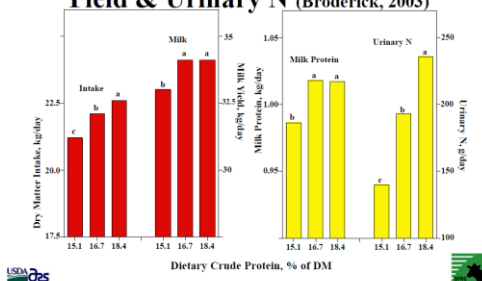
Effect on Production & Efficiency of Replacing SBM-CP with Protected-Met

% CP/RP-Met
- 18.6%/0
- 17.3%/5 g
- 16.1%/10 g
- 14.8%/15 g

Milk (kg/d); N-efficiency (%) & MUN (mg/dl) — Milk, N-efficiency, MUN, Urinary-N

a-d(P < 0.05); RP-Met = g Rumen protected Met/d from Mepron

Slide 2
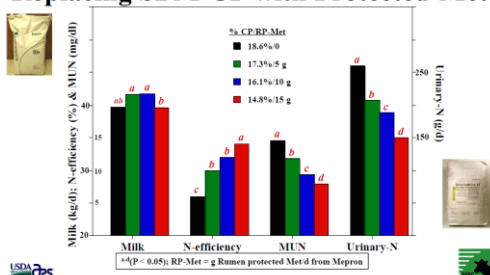
Feeding multiple rations would help N efficiency

- Later lactation cows require lower protein density than early lactation cows
- Feeding lower protein diets in later lactation can reduce herd N input without hurting milk production
- Group feeding can also help in managing for body condition

Slide 3

Rumensin improves feed efficiency & diet energy utilization in mid lactation cows

	UW Trial 1 Akins et al., 2014		UW Trial 2 Hagen et al., 2014	
	Rumensin vs. Control	P-value	Rumensin vs. Control	P-value
MILK/DMI	+4.0%	0.01	+3.4%	0.03
ECM/DMI	+3.2%	0.03	+3.9%	0.02
Diet NEL	+2.5%	0.01	+4.6%	0.01

(MilkE + MaintE from BW + BWΔE) / DMI

Rumensin effects observed in Normal or Reduced starch diets (Akins et al.), & in diets with or without amino acid balancing (Hagen et al.)

**Recent UW Continuous-Lactation Trials
With High Fiber, Low Starch Byproducts**

	DIM at Trial Start-Up	Weeks on Trial	Dietary Forage NDF	Diet Starch NS - RS	Partial Corn Replacers
UW I	51	14	21%	5%	SH
UW II	68	12	20%	5%	WM, WCS
UW III	114	14	21%	10%	SH
UW IV	100	16	21%	6%	SH

Reduced-Starch Diets

- Reduced gross feed efficiencies by 2%-12% for Milk/DMI and 1%-11% ECM/DMI

- Reduced feed cost per unit DM by 1%-8%

- Increased feed cost/cow/day by 3%-8% in 2 trials and reduced it only by 1%-2% in 2 trials

- Reduced IOFC by 4%-7% in 3 trials with no change in 1 trial

Reduced-Starch Diets

- Ruminal propionate impacts DMI, milk yield & composition, & feed efficiency

- Multiple ration groups for lactating cows important for effectively implementing

- Partial replacement of forage-NDF with byproduct-NDF may be more effective formulation strategy

Acknowledgments

Slides of:

Mike VandeHaar (Michigan State University)
Lou Armentano & Kent Weigel (UW Madison)
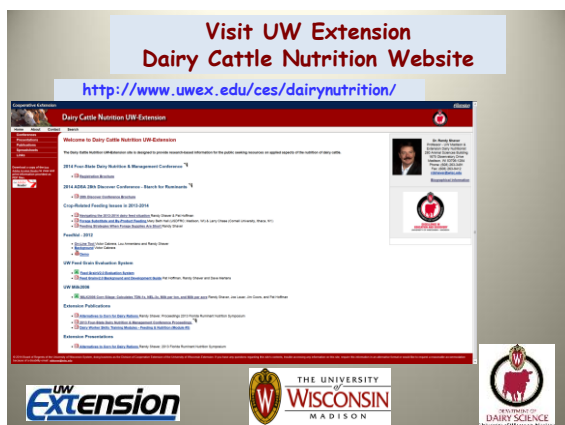**Glen Broderick (UW Madison & USDFRC)**

Visit UW Extension
Dairy Cattle Nutrition Website

http://www.uwex.edu/ces/dairynutrition/